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Teutsch, Uwe ; Knechtle, Beat ; Rüst, Christoph Alexander ; Rosemann, Thomas ; Lepers, Romuald

Abstract: BACKGROUND: Participation and performance trends in age group athletes have been investigated in endurance and ultraendurance races in swimming, cycling, running, and triathlon, but not in long-distance inline skating. The aim of this study was to investigate trends in participation, age, and performance in the longest inline race in Europe, the Inline One-Eleven over 111 km, held between 1998 and 2009. METHODS: The total number, age distribution, age at the time of the competition, and race times of male and female finishers at the Inline One-Eleven were analyzed. RESULTS: Overall participation increased until 2003 but decreased thereafter. During the 12-year period, the relative participation in skaters younger than 40 years old decreased while relative participation increased for skaters older than 40 years. The mean top ten skating time was 199 ± 9 minutes (range: 189-220 minutes) for men and 234 ± 17 minutes (range: 211-271 minutes) for women, respectively. The gender difference in performance remained stable at $17\% \pm 5\%$ across years. CONCLUSION: To summarize, although the participation of master long-distance inline skaters increased, the overall participation decreased across years in the Inline One-Eleven. The race times of the best female and male skaters stabilized across years with a gender difference in performance of $17\% \pm 5\%$. Further studies should focus on the participation in the international World Inline Cup races.

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Age group athletes in inline skating: decrease in overall and increase in master athlete participation in the longest inline skating race in Europe – the Inline One-Eleven

Uwe Teutsch¹

Beat Knechtle^{1,2}

Christoph Alexander Rüst¹

Thomas Rosemann¹

Romuald Lepers³

¹Institute of General Practice and Health Services Research, University of Zurich, Zurich, Switzerland;

²Gesundheitszentrum St Gallen, St Gallen, Switzerland; ³INSERM U1093, Faculty of Sport Sciences, University of Burgundy, Dijon, France

Background: Participation and performance trends in age group athletes have been investigated in endurance and ultraendurance races in swimming, cycling, running, and triathlon, but not in long-distance inline skating. The aim of this study was to investigate trends in participation, age, and performance in the longest inline race in Europe, the Inline One-Eleven over 111 km, held between 1998 and 2009.

Methods: The total number, age distribution, age at the time of the competition, and race times of male and female finishers at the Inline One-Eleven were analyzed.

Results: Overall participation increased until 2003 but decreased thereafter. During the 12-year period, the relative participation in skaters younger than 40 years old decreased while relative participation increased for skaters older than 40 years. The mean top ten skating time was 199 ± 9 minutes (range: 189–220 minutes) for men and 234 ± 17 minutes (range: 211–271 minutes) for women, respectively. The gender difference in performance remained stable at $17\% \pm 5\%$ across years.

Conclusion: To summarize, although the participation of master long-distance inline skaters increased, the overall participation decreased across years in the Inline One-Eleven. The race times of the best female and male skaters stabilized across years with a gender difference in performance of $17\% \pm 5\%$. Further studies should focus on the participation in the international World Inline Cup races.

Keywords: endurance, men, women, gender

Introduction

The popularity of endurance sports increased in the last decades. For half-marathons and marathons, the participation has changed over the years. While the overall participation increased for marathons and ultramarathons,^{1–3} the age pattern changed. Jokl et al⁴ showed that for the New York City Marathon, participation for athletes in the 10–19-year age group decreased, while participation among athletes aged 30–59 years showed a remarkable increase. The finding of an increased participation of master athletes was verified by other authors in marathon running and ultramarathon running.^{3,5–10} Other endurance competitions held in ultraswimming,^{11–14} ultracycling,^{15–19} and ultratriathlons started in the late 20th century.^{20–22}

Apart from an increase in master athletes, the increase in female participation was also attributed to an increase in the overall participation in marathon running.⁴ Female participation in endurance and ultraendurance events increased from the early 1980s

Correspondence: Beat Knechtle
Facharzt FMH für Allgemeinmedizin,
Gesundheitszentrum St Gallen,
Vadianstrasse 26, 9001 St Gallen,
Switzerland
Tel +41 071 226 8282
Fax +41 071 226 8272
Email beat.knechtle@hispeed.ch

to the present. Jokl et al⁴ reported that for the New York City Marathon, female participation increased at a greater rate than male participation between 1983 and 1999. Based on the decline in the ratio of male to female runners from 5.6:1 in 1983 to 2.47:1 in 1999, and assuming that this pattern would continue, the authors expected the ratio to approach 1:1 in 2007.⁴ Participation of female athletes in ultraendurance events exhibited a similar trend. Female participation in ultramarathons such as the Western States 100 Mile Endurance Run progressively increased from 10%–12% of the field in 1986 to 20%–22% since 2001.³

It has been assumed that gender differences in performance would vanish for longer running distances in the future.²³ Although women improved performance at a greater rate than men, there is still a small gap in performance between women and men. Based on the analysis of the world's best running times from 1980 to 1996 for races of 1500 m and the marathon distance, Sparling et al²⁴ concluded that distance running performances for women had reached a plateau after demonstrating an initial improvement. The comparison of the top 50 running times among women and men showed a gender difference in performance of 10%–13%. The reason behind the conclusion that women would outrun men sooner was a comparative analysis of recent or future performances.^{23,25} Coast et al²⁶ investigated the gender difference in performance for distances between 100 m and 200 km and showed that men were ~12% faster than women. Longer distances were associated with a greater gender difference in performance.²⁶ For the ultramarathon distances, female performance improved relative to men throughout the 1980s, but in the past two decades, the average times of the fastest runners showed no change for either gender.²⁶ The fastest women are still running ~20% slower than the fastest men.²⁷

Another key topic addressed in recent years was the investigation of endurance performance related to the age of the athletes.^{4,5,28,29} It was widely accepted that endurance performance showed an age-related decline, as reported for running and for other disciplines such as swimming and triathlon.^{6,28,30–37} Recent research showed that master athletes, defined as athletes older than 35 years,³⁸ improved their performance times at a higher rate than younger athletes.^{1,4–6,28} Thus, the argument of a decline in endurance performance with advancing age beyond the age of 30–35 years needs to be questioned.^{39–41} The analysis of finishing times of trained endurance athletes showed that the decline in running performance started after the age of 50 years, and that the decline in performance of runners aged beyond 35 years was mostly

due to physical inactivity and negative lifestyle factors (eg, smoking, malnutrition, or overnutrition).²⁸

Apart from the traditional endurance sports running,^{1–6} cycling,^{15–18} and swimming,^{11–14} new sports disciplines were created in the last two decades, such as long-distance inline skating.^{42–45} In the early 1990s, the popularity of inline skating showed an enormous increase, leading to inline-speed skating competitions, like sprint races or marathon races such as the Athens-2-Atlanta (86 miles = 138.4 km).⁴⁶ Inline speed skating is a special endurance discipline because of its technical aspect. Special skates are used where the number, size, and hardness of the wheels can be changed and may affect performance.⁴³ According to the race track, the skaters can assemble their skating shoes especially for each road. The use of ordinary skates or custom-made skates, and the different wheel bearings can have a remarkable effect on performance. Apart from anthropometry, training, and pre-race experience, equipment is the most important variable for performance of nonexperienced skaters. Performance of experienced skaters who know their equipment relies upon body mass, skin-fold thickness, and body fat.⁴⁴

Recent studies have investigated participation and performance trends for marathon races like the New York City Marathon,¹ or ultramarathon and long-distance triathlon events like the Ironman Hawaii,²⁰ but to date there is no data available on participation and performance trends in inline speed skating races. Studies focused on predictor variables in athletes competing in the long-distance speed skating race, Inline One-Eleven.^{42,44} Knechtle et al⁴² investigated female finishers in the Inline One-Eleven, showing that body height, age, and duration of each training unit were the best predictor variables for female ultraendurance inliners. An investigation focusing on male participants in the Inline One-Eleven demonstrated that the performance of experienced long-distance skaters relied upon body mass, skin-fold thickness, and body fat.⁴⁴

Participation and performance trends in endurance and ultraendurance races have been investigated for different sports disciplines such as swimming,^{11–14} road cycling,^{15–17} mountain bike cycling,^{18,19} running of different distances,^{2–4,7,9,47–50} wheelchair cycling,^{51,52} duathlon,⁵³ and triathlon of different race distances;^{20,22,35–37,54} however, these were not investigated for long-distance inline skating. The aim of the present study was to investigate the participation and performance trends of the Inline One-Eleven held in Switzerland from 1998 to 2009. The Inline One-Eleven was the longest inline skating race in Europe, covering the total distance of 111 km with a total altitude of 1400 m to climb. The start of the race was in the heart of the city of

St Gallen, Switzerland, and then went on to a large loop of 111 km in the east of Switzerland, returning to St Gallen. The race took place each year at the beginning of June. Inline skaters from all over Europe came to St Gallen for the longest inline race in Europe, held on completely closed routes, where drafting was allowed. Due to increased costs, a lack of sponsoring, and a decreased number of participants (only 900 athletes participated in the last race in 2009), the Inline One-Eleven was suspended. According to existing literature, we hypothesized that (1) overall participation in the Inline One-Eleven increased across years; (2) performance of the best athletes improved during the 12-year period of the race; and (3) participation of women and master athletes increased.

Methods

This study was approved by the institutional review board of St Gallen, Switzerland, with a waiver of the requirement for informed consent given that the study involved the analysis of publicly available data. All race results were provided by the race director. The age at the time of the competition, as well as race times of male and female finishers at the Inline One-Eleven were analyzed from the first race held in 1998 to the last race held in 2009.

Data analysis

Winner and top ten overall performances

The age at the time of competition and race times of the annual winners and the annual top ten men and women were analyzed from 1998 to 2009. Data (ie, ages and race times) were averaged across the first ten female and male finishers for each year from 1998 to 2009. Race times were converted to minutes. The magnitudes of the gender difference were examined by calculating the percent difference for the race times of the male versus female winners and of the top ten men versus the top ten women.

Age-related changes in performance

We distinguished between the age group categories of 18–24 years, 25–29 years, 30–34 years, 35–39 years, 40–44 years, 45–49 years, 50–54 years, 55–59 years, 60–64 years, and 65–69 years. Due to the low number of female finishers over 59 years, the last female age group analyzed was 55–59 years. We therefore considered only the performances of the best 50 male and the best 20 female skaters per age group during the 12-year period. This differentiation was selected due to the lower number of women compared to men. For this period, the skating time

performances of the best 50 male and the best 20 female skaters per age group was expressed in terms of the percent-age of winner performance times.

Statistical analysis

Data are reported as means \pm standard deviation in the text. Linear regressions were used for estimating the changes of selected variables per year. Pearson's correlation coefficients were used to assess the association between variables (Statistica version 6.1; StatSoft, Inc, Tulsa, OK, USA). The age of the female versus male winners was compared using an unpaired Student's *t*-test. To determine if the age of the top ten male and the female finishers differed across years, an analysis of variance (ANOVA) with repeated measures on year with gender as the between-subject factor was performed. One-way ANOVA was used to compare the race times between the different age groups for both men and women. Tukey's post hoc analyses were used to test differences within the ANOVA when appropriate. Statistical significance was accepted at $P < 0.05$.

Results

Participation trends

The Inline One-Eleven started in 1998. In the 12-year period, a total of 8662 finishers could be counted with 1463 female and 7199 male finishers. The number of male finishers indicated a slight increase from 322 to about 500 in the following years until 2002, and then a sharp rise was observed, with a peak of 1026 finishing men in 2003, which was twice as many as in 2002. The number of finishers each year over the history of the event is shown in Figure 1. Between 1998 and 2009, the average number of finishers per year was 600 ± 190 (range: 322–1026) for men and 122 ± 50 (range: 44–209) for women, respectively. The number of female finishers showed a constant increase from 44 in 1998 to 209 in 2003. Then, the number of finishers showed a constant deterioration again to about 500 men and 100 women finishing the race in 2009. Women accounted on average for $16.5\% \pm 2.2\%$ of the field over the 12-year period.

Age of the skaters

The age distribution of both female and male finishers during the 12-year period is presented in Figure 2. The 5-year age brackets with the greatest participation were 30–34 years for women and 35–39 years for men. Skaters older than 40 years represented ~41% of male finishers and 23% of female finishers. The changes in the percent-age of finishers per age group from 1998 to 2009 for both

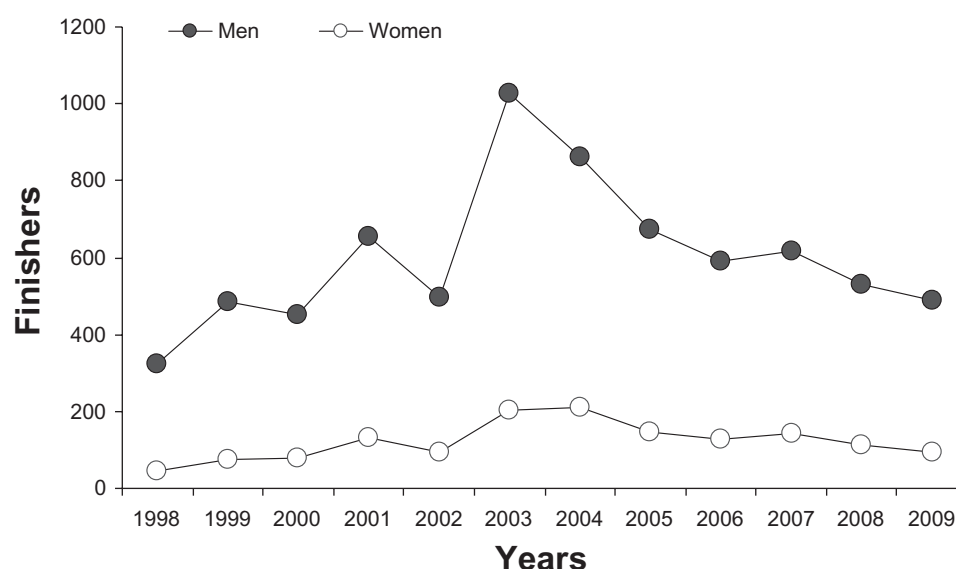


Figure 1 Number of finishers at the Inline One-Eleven for each gender from 1998 to 2009.

men and women are shown in Figure 3. For both men and women, the percentage of finishers decreased over the 13-year period for age groups 20–29 years (men: $r = -0.82$, $P = 0.0011$; women: $r = -0.70$, $P = 0.011$) and 30–39 years (men: $r = -0.87$, $P = 0.0002$; women: $r = -0.53$, $P = 0.075$), while it increased for age groups 40–49 years (men: $r = 0.95$, $P = 0.0001$; women: $r = 0.87$, $P = 0.0002$) and 50–59 years (men: $r = 0.86$, $P = 0.0003$; women: $r = 0.87$, $P = 0.0002$). The percentage of finishers increased for the men's age group 60–69 years (men: $r = 0.93$, $P = 0.0001$), but remained low and stable for the women's age group

60–69 years (women: $r = -0.57$, $P = 0.06$). The ages of both male and female winners are shown in Figure 4A. The ages of the female winners (25.5 ± 3.6 years) were not significantly different compared to male winners (27.5 ± 3.7 years). Because one-way ANOVA showed no significant difference for the top ten female and male race times between 1998 and 2009, data were pooled together to analyze the age-related changes in skating performances. The mean ages of the top ten placed females and males were 25.8 ± 2.3 years and 26.2 ± 1.8 years, respectively (Figure 4B).

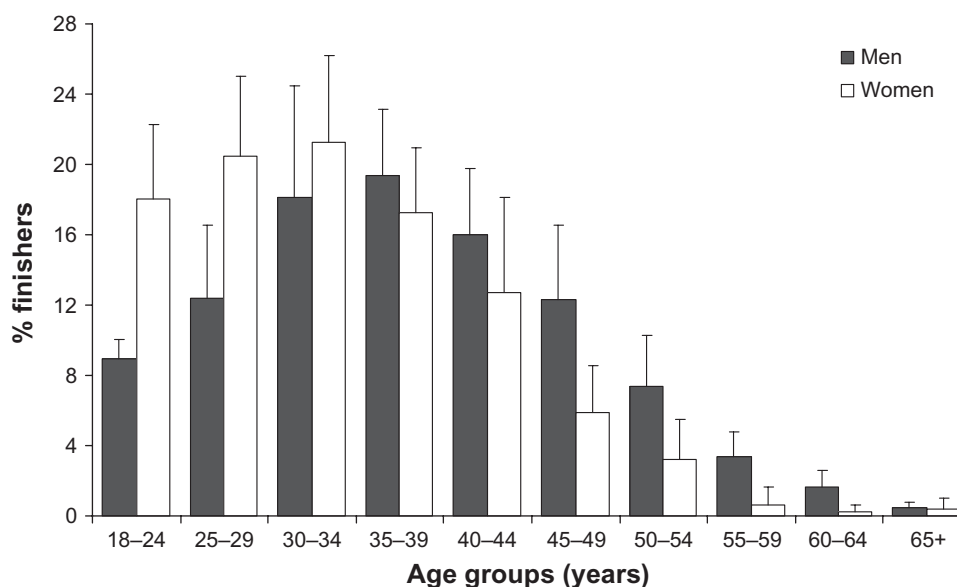


Figure 2 Percentage of female and male finishers per age group over the period 1998–2009.

Note: Values are the mean \pm standard deviation.

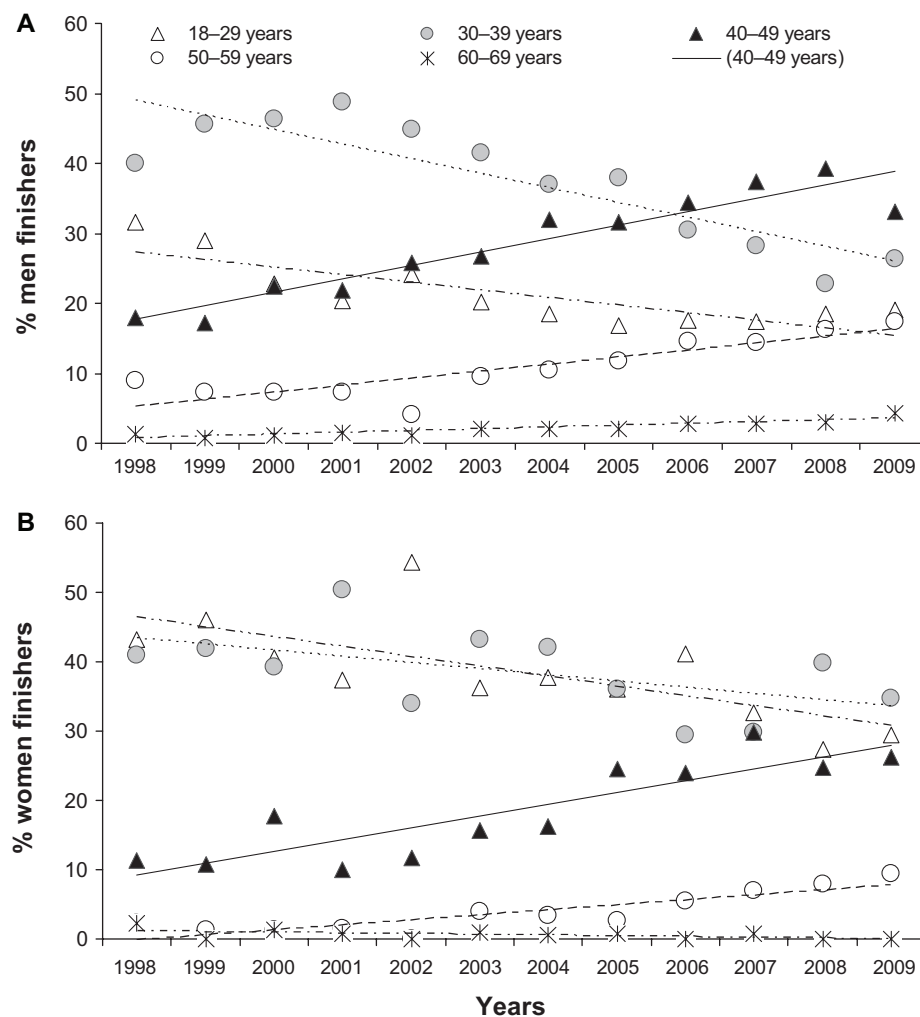


Figure 3 Changes in percentage finishers per age group from 1998 to 2009. (A) Men; (B) Women.

Winner and top ten performance trends

Figure 5A shows the historical performance trends for female and male winners during the studied period. The mean winner race time was 194 ± 8 minutes (range: 187–214 minutes) for men and 223 ± 15 minutes (range: 208–267 minutes) for women. The average time difference between female and male winners over the 1998–2009 period was equal to $15\% \pm 5\%$ (range: 9%–25%). Figure 5B shows the historical performance trends of the top ten men and women during the 12-year period. The mean top ten race time was 199 ± 9 minutes (range: 189–220 minutes) for men and 234 ± 17 minutes (range: 211–271 minutes) for women. The average time difference between the top ten men and women over the 1998–2009 period was equal to $17\% \pm 5\%$ (range: 9%–24%).

Age-related changes in performance

The mean age-related changes for both female and male race times throughout the 1998–2009 period are presented

in Figure 6A. The race times increased in a curvilinear manner with advancing age. There was a significant ($P < 0.0001$) age effect for both female and male race times. No significant difference in time was observed for the three age groups between 18–24 years and 30–34 years for both women and men. For women and men, race time was significantly ($P < 0.01$) greater for the age group 40–44 years and older when compared to the age groups between 18–24 years and 30–34 years. Figure 6B shows the age-related changes in skating performance expressed as a percentage of the winner race time. Compared to the winner, the oldest female age group (55–59 years) was on average $51\% \pm 18\%$ slower, while the oldest male age group (65–69 years) was on average $62\% \pm 20\%$ slower.

Discussion

The aims of the present study were to investigate the participation and performance trends of inline skaters competing

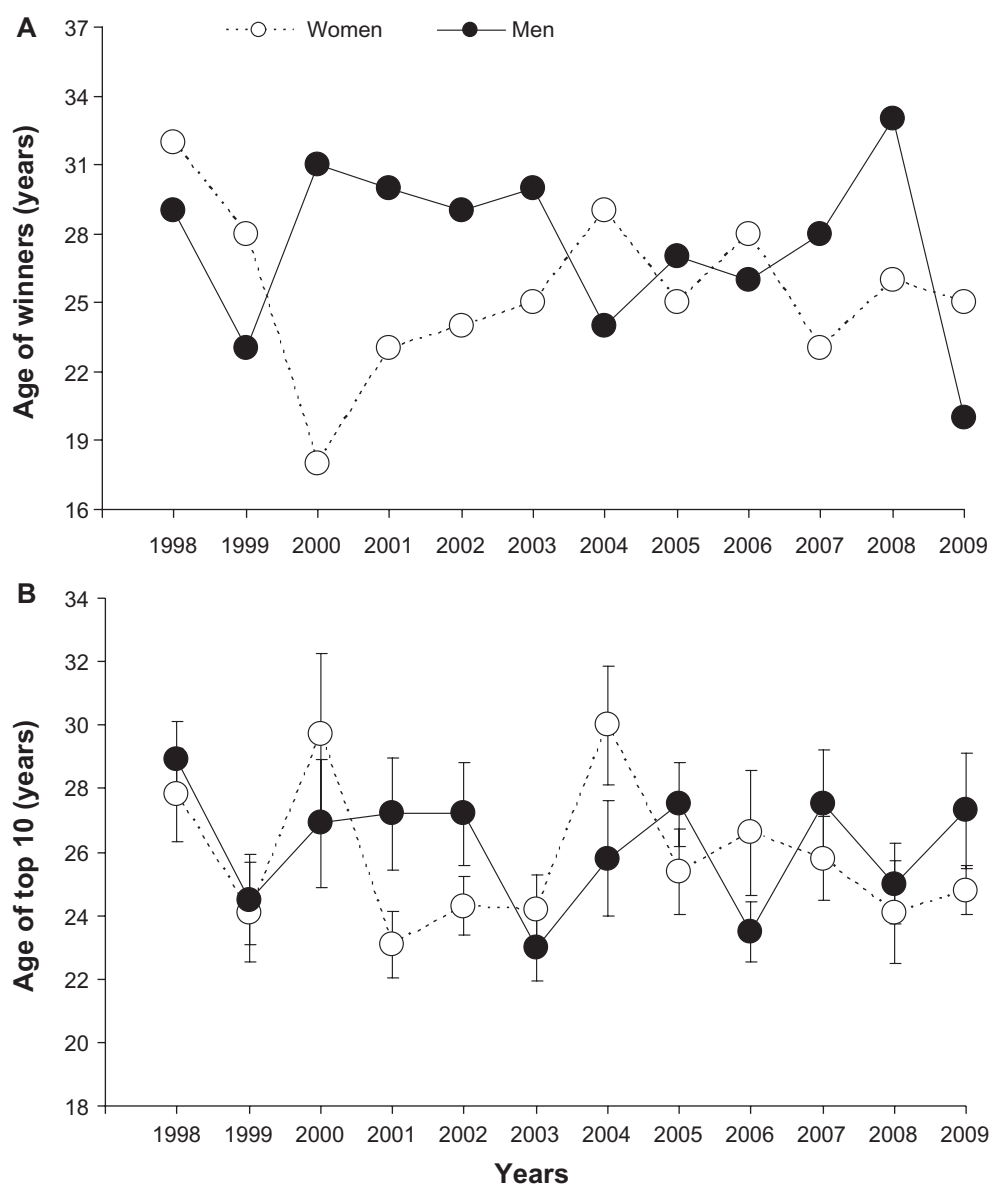


Figure 4 Age of the overall winners and top ten female and male athletes at the Inline One-Eleven from 1998 to 2009. **(A)** Age of the female and male winners from 1998 to 2009. **(B)** Mean (\pm standard error) age of the overall top ten female and male finishers from 1998 to 2009.

in the Inline One-Eleven held in Switzerland, which was the longest inline skating race in Europe from 1998 to 2009. The main findings were: (1) that after an initial increase from 1998 to 2003, the overall participation rate in the Inline One-Eleven decreased; (2) the relative participation for skaters older than 40 years increased while it decreased for skaters younger than 40 years over the whole period; and (3) the mean top ten race times remained stable for both men and women.

Participation in Inline One-Eleven

This is the first study to describe the participation and performance trends of inline skaters in an endurance race such as the Inline One-Eleven. In contrast to our hypothesis, the

participation in the race increased only in the beginning years of the race; after 2003, the number of participants diminished until the race was cancelled in 2009. The race was discontinued due to the decreasing number of athletes taking part in the race; other reasons included increasing costs and reduced sponsorship. These findings were in contrast to reports on participation trends in other disciplines like marathon running,^{4,6} ultramarathon running,^{2,3} and the Ironman triathlon,^{20,55} where participation is still growing. One reason for the decreased participation in the Inline One-Eleven could be the general diminishing interest in inline skating.⁵⁶ Later, the so-called “trend sport” of inline skating normalized to a public sport and lost its distinctiveness. The

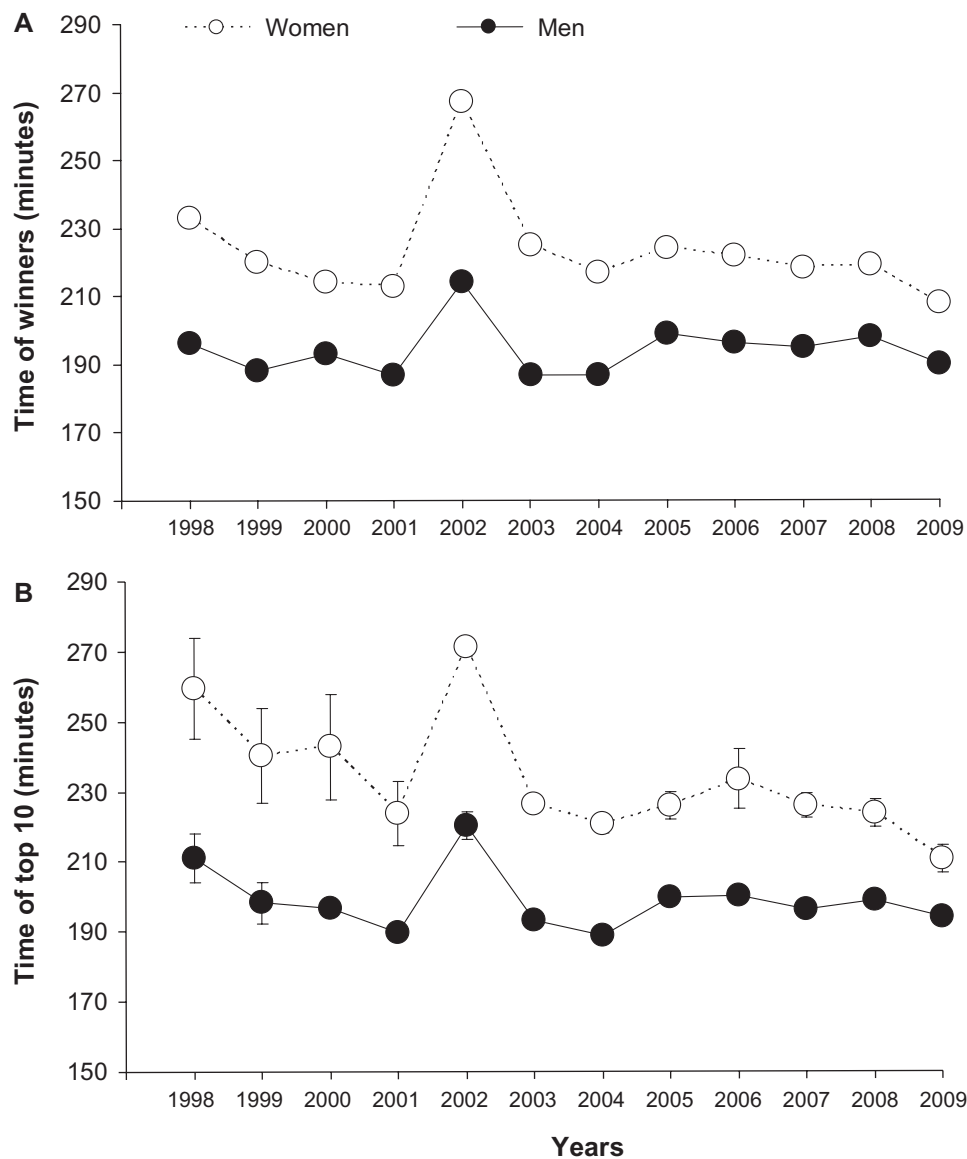


Figure 5 Performance times of the overall and top ten female and male winners at the Inline One-Eleven from 1998 to 2009. **(A)** Performance times of the overall female and male winners at the Inline One-Eleven from 1998 to 2009. **(B)** Mean (\pm standard deviation) performance times of the overall top ten female and male finishers from 1998 to 2009.

beginning of the 21st century showed shrinking sales volume and a general diminished interest in inline skating, which may be caused by a lack of acceptable roads where inline skating is allowed. Considered pedestrians, inline-skaters had to use walkways for their sport, which were not adequate at all. In 2009, the Swiss Inline Cup consisted of eight inline events held throughout Switzerland.⁵⁷ Today, a few years later, there are only two of these events left; interestingly, these two events are characterized by a maximum length of 42 km and a very short lap distance.⁵⁴ There seemed to be a trend towards shorter races, which has also been shown for the Swiss Bike Masters, where the participation showed a dramatic decline since 1998.^{18,19} In addition, there was a

tendency of internationalizing the disciplines, leading to more concurrent races worldwide.^{58,59} The resulting effect was that the number of races in every country decreased, such that there existed an acceptable level of participation for at least one or two events every year. Another reason was the fact that inline skating races like the Inline One-Eleven were not considered as ultraendurance events due to their duration of less than 6 hours which, like the Ironman triathlon or the 161 km marathon, still exhibit increasing participation.^{2,6}

This decrease in overall participation might have had a considerable influence on the participation among different genders and age groups. Over the 12-year period studied, the percentage of finishers decreased for athletes in age

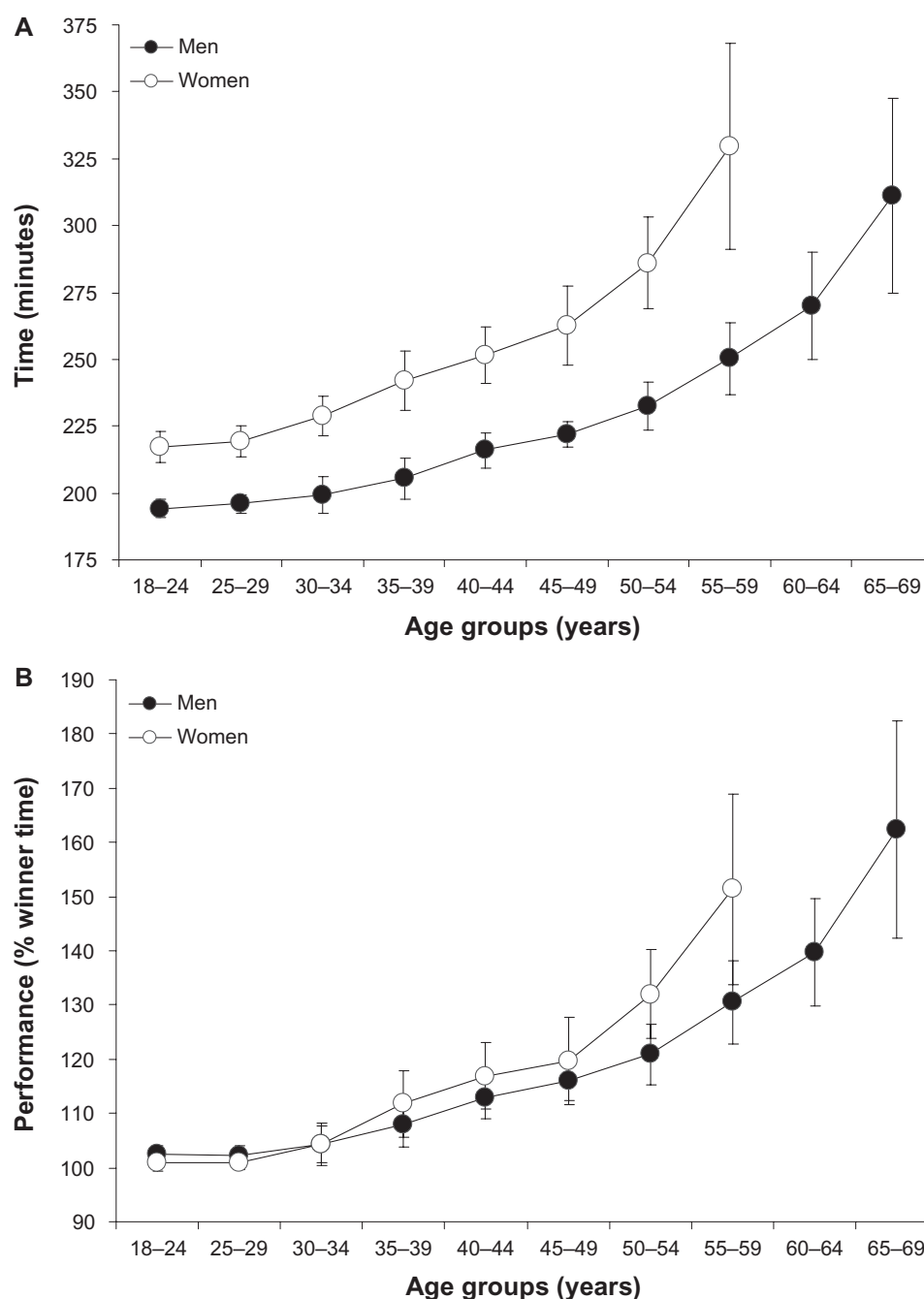


Figure 6 Age-related changes in skating performances at the Inline One-Eleven. **(A)** Age-related changes in skating performances at the Inline One-Eleven. Data were pooled from 1998 to 2009. Values are means \pm standard deviations. The best 50 male and 20 female skaters per age group were considered during the 12-year period. For men and women, skating times were significantly greater ($P < 0.01$) for the age group 40–44 years and older compared to age groups between 18–34 years and 30–34 years. There was no significant difference between the three age groups 18–24 years, 25–29 years, and 30–34 years for both women and men. **(B)** Age-related changes in skating performances when performance is expressed as a percentage of the winner time.

groups 20–29 years and 30–39 years, while it increased for athletes in age groups 40–49 years and 50–59 years for both men and women. The percentage of finishers slightly increased for men in age group 60–69 years and remained low and stable for women in the age group 60–69 years. These changes in participation might have influenced the statistical analyses.

Age of participants and performances

A further important finding was that the participation rates for men and women decreased for athletes in the 20–39-year age group, while participation for athletes in the 40–59-year age group showed a remarkable increase. This was expected because similar results were found for other endurance performances like the marathon and half-marathon.^{4–6}

This could be due to the idea that younger individuals regard endurance sports as leisure activities, and therefore they might quit this type of activity much easier. In contrast, master endurance athletes older than 35 years often practice their endurance sport in order to improve their general physical fitness or to partake in the sport as a health precaution. Older athletes may need more training to achieve their optimal physical condition to take part in an endurance event. Most likely, there must be a greater motivation for athletes to train for an endurance performance event, and therefore the impetus of maintaining the physical status has to be greater. There was a general trend towards an increasing number of healthy aging people in the population being physically able to participate in these events.⁴

The analysis of the age-related performances exposed several findings. The ages of female and male winners were not significantly different with women aged 25.5 ± 3.6 years and men aged 27.5 ± 3.7 years. The mean age of the top ten women and men across the years remained quite stable at 25.8 ± 2.3 and 26.2 ± 1.8 years, respectively. Similar age patterns were found in marathon running where the top female and male finishers were in their late 20s.⁶⁰ This was in contrast to the results from ultramarathon races like the 100 km Lauf Biel, where the finishers in the age groups younger than 30 years were slower than finishers in the age groups between 30 and 50 years.⁵⁰ Other studies regarding ultraendurance performance such as the 161 km marathon also showed faster racing times for older participants aged 30–50 years.² It seemed that the race times of older participants improved with increasing length of the race.^{10,48}

According to Zaryski and Smith,⁶¹ ultraendurance is defined as competitions lasting at least 6 hours, and successful performance relies on long-term preparation, sufficient nutrition, and accommodation of environmental stressors and psychological toughness. It seemed that these demands were met better by older athletes than by younger ones. The athletes had on average less than 6 hours to complete the race, so it is no ultra-endurance race by definition. This was consistent with the finding that the fastest racers were in the age group 20–29 years, and not in the older groups.

Gender differences in participation and performance

Regarding participation, female participation was parallel to male participation across years, irrespective of the high rate of male participation in 2003 and 2004, and the decrease in the last years of the race. The rate of female participants was quite

stable at ~16% of all skaters over the 12-year period. This is in contrast to existing reports about participation in ultraendurance races, where the participation of women and older athletes increased across years.^{2,3} This could be due to the fact that the Inline One-Eleven was not an ultraendurance race.

The highest number of female finishers during the whole 12-year period was observed in the age group 30–34 years, which was quite similar to male participation where the largest group was the age group 35–39 years. Data about the Western States 100 Mile Endurance Run showed the largest participation in the age group 40–44 years for both genders. The percentage of skaters older than 40 years of age was 41% for men and 23% for women. Regarding the percentage of finishers per age group, there was no remarkable difference between women and men. Comparing the ages of male and female winners, there was no significant difference between women aged 25.5 ± 3.6 years and men aged 27.5 ± 3.7 years. Additionally, no difference was apparent in the mean age of the top ten women and top ten men with ages of 25.8 ± 2.3 years and 26.2 ± 1.8 years, respectively.

We also compared the winners and the top ten performances of women and men. The mean winner race time for men was 194 ± 8 minutes and 223 ± 15 minutes for women, which means an average time difference between men and women winners of $15\% \pm 5\%$ over the studied period. The investigation of the top ten winning times of men and women demonstrated similar results. In running disciplines, females were slower than males and the gender difference increased with increasing race distance.²⁶ Comparing the winner times since 2003, the reduction of the gap between the males and females indicates that females showed better improvement than their male counterparts and probably would have outpaced men in the long run.

Limitations

This cross-sectional data analysis is limited due to the lack of inclusion of training characteristics,⁴⁴ previous experience,⁴⁵ anthropometric characteristics,⁴² aspects of equipment,⁴³ and influence of weather and environmental conditions in the analysis.^{12,53} Some athletes might have participated in the race several times across different years, and the inclusion of repeated athletes might have had an influence on the statistical analysis. The nonfinishers were not included due to missing data for nonfinishers in the race results. The inclusion of nonfinishers would give an insight as to whether more women than men were not able to finish the race, and whether more older than younger athletes were among the nonfinishers.⁶²

Conclusion

To summarize, overall participation in a long-distance inline skating race such as the Inline One-Eleven decreased, while participation of master athletes increased during the 12-year period. The female participation rate of $16.5\% \pm 2.2\%$ and the gender difference in performance of $17\% \pm 5\%$ for the annual top ten women and men remained stable. The mean age of the top ten female and male runners was ~26 years, which was similar to recent findings in marathon and half-marathon distance performances. The race times of the best female and male skaters stabilized across years. The decrease in overall participation was an unexpected finding. Inline skating events with national and international championships are still taking place all over the world. The standard distance for international races is 42 km, with shorter courses increasing in popularity. Further studies should focus on the participation in the international World Inline Cup races. To date, the majority of studies are focusing on injuries related to inline skating. A comparison of participation in nontraditional endurance races such as inline skating and mountain-biking would also be of interest.

Disclosure

The authors report no conflicts of interest in this work.

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